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Technical Note N-825

REMOVAL OF OIL AND DEBRIS FROM HARBOR WATERS

BY

Georg E. Beduhn, DEng

July 1966

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Internal Working Paper

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U. S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

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REMOVAL OF OIL AND DEBRIS FROM HARBOR WATERS

Technical Note N-825

Y-F015-99-01-400

by

Georg E. Beduhn, DEng

ABSTRACT

The technical note comprises a short survey of methods and equipment utilized in major harbor systems to clean water of oil and debris. Oil spills are removed by mechanical or chemical means. Most mechanical equipment employs an oil skimmer, vacuum nozzles, or rotating cylinders to collect the oil. Chemical agents - in general liquids - are sprayed on the oil slick through nozzles. Rated against a list of requirements, none of these methods are completely satisfactory. Debris collection methods are outdated and mostly done by hand for lack of suitable equipment. Some of these methods are recommended for future development.

INTRODUCTION

This investigation of methods and equipment utilized in major harbor systems to clean the water of oil and debris was initiated in response to a request from the Pearl Harbor Naval Shipyard. The objective was to conduct a preliminary study of the state of the art in harbor cleaning operations and to establish a basis for a more thorough investigation. The study is based mostly on information received from harbor officials of Norfolk, San Diego, Baltimore, Long Beach, and Pearl Harbor and on demonstrations observed at the first two places.

Generally, it was found that the pollution of harbor waters by oil and debris is a problem encountered in almost all harbors, and one which is controlled with various degrees of success. The methods of oil and debris removal, however, differ from port to port in conditions and significance and in means of solution for the following principal reasons:

1. Configuration and location of harbor
2. Size of harbor
3. Construction of piers
4. Kind of harbor activity
5. Wind direction, tide and current
6. State laws for fish and game protection

Figure 1 compares the topography of San Diego and Pearl Harbor and illustrates the differences of the problem at two locations. The water area of San Diego is more than three times as large as that of Pearl Harbor; tide action in San Diego causes currents up to 2.5 knots and oil slicks in these areas move fast. Therefore, oil removal actions have to start immediately after spillage in order to protect such areas as the small boat harbor. No problem like this arises in Pearl Harbor because the tide variation is small. While San Diego has almost no debris, this is a big problem in Pearl Harbor. During periods of heavy rain, many small streams carry debris into Pearl Harbor where the prevailing winds move it to the shipyard which becomes a "catch basin" for most flotsam. This example illustrates that a general solution to all harbor cleaning problems can hardly be expected. In any case, the most economical method must be based on the individual characteristics of each harbor. For this reason, harbor cleaning methods currently in use differ widely from port to port.

For subsequent discussion, it seems logical to treat "Oil Removal" and "Debris Collection" separately. The first part of the technical note contains a discussion of oil removal by mechanical and chemical means. The section on mechanical oil recovery deals mainly with the Baltimore Method, oil skimmer systems, and oil booms. The following section reviews a number of chemical agents and describes the San Diego method of oil dissipation. The second part of the note gives a brief survey of debris collection.

OIL REMOVAL

From the introduction, it is evident that there is little agreement among port officials regarding the most satisfactory and economical method for oil removal. The following list gives the basic features of an effective and efficient oil removal system:

1. Reasonable first cost
2. Low operating expense
3. Minimum maintenance requirements
4. Rapid recovery rate or high removal potential
5. Minimum need for auxiliary equipment
6. Relative insensitivity to water motion and waves
7. High mobility and maneuverability
8. Compatibility with marine life

Even though the compatibility with marine life is listed last, this point is extremely important because the protection of marine life is one of the main objectives of pollution control. The practical methods of oil removal fall into the two categories of mechanical oil recovery and of oil dissipation by chemical means.

Mechanical Oil Recovery Methods

The most effective method to control water pollution is undoubtedly to remove the oil entirely from the harbor waters. This can only be achieved by mechanical oil recovery methods, but involves, in almost all cases, investment in costly equipment. The methods and equipment described in the next paragraphs will be judged on the basis of the requirements listed previously.

The Baltimore Oil Recovery Barge. The vessel is a modified barge and is self-propelled by means of a 52 horsepower diesel-powered outboard propulsion and steering unit.[1] The propulsion of the 38-foot vessel is primarily intended for moving the barge from a station to the location of an oil spill. The oil recovery unit, based on the Earle System, is mounted in a sump at the forward end of the barge as shown in Figure 2.

In principle, the Earle System is based upon oil adhesion to a rotating cylinder. Only oil adheres to the special surface of the cylinder while the water is rejected; a wiper blade removes oil from the rotating cylinder. A small engine drives a hydraulic power generator for operation of the hydraulic motor of the pickup cylinder.[2]

The unit in the oil recovery barge uses a total of four pickup cylinders, arranged as in Figure 3. The three outside cylinders transfer the oil into an inside sump, where it is picked up by the fourth drum for deposit into a 3,000 gallon storage tank in the body of the barge. All cylinders are submerged about 9-inches-deep into the water.

The system has been tested with 11 types of oil, including Bunker C, diesel oil, and gasoline, and has proved an average retrieving ability of more than 90% oil and less than 10% water, depending on the type of oil being removed. The best results are obtained with the more viscous oils. It is, however, pre-requisite that the speed of cylinder rotation is accurately and constantly controlled to prevent air and water inclusion in higher percentages.

To increase effectiveness of the Earle System, a floating oil boom is normally used with the barge and the confined oil slick is drawn toward the oil recovery unit; various types of oil booms are described on the following pages. In addition to increasing film thickness by means of an oil boom, lower oil temperatures, higher oil viscosity, assured oil film contact, and proper cylinder speed will improve the oil recovery rate.

In rating the features of the Earle System according to the list of requirements established above, it will be seen that: the oil recovery barge is fairly expensive (approximately $100,000), and it needs a crew of more than two men; an auxiliary oil boom is also required. Only through field tests it will be possible to determine maintenance requirements and sensitivity of the system to water motion. Its oil recovery rate, however, mobility and compatibility with marine life are apparently satisfactory. Since the Baltimore barge is the only one of its kind in existence, the experience gained so far is limited. A more thorough investigation will be necessary for a meaningful judgement.

Oil Skimmer Systems. Oil skimmers attempt to skim off the oil film by means of a weir or a ramp which has to be adjusted just below the water surface. It can be either part of a vessel itself or a separate unit fastened to it. The oil-water mixture is collected in a sump and from there pumped to the storage tank. The best known example of this kind is the so-called "Norfolk Oil Skimmer."[3]

This oil skimmer may be described as a 25 x 12-foot box-shaped barge with holes in the bottom to permit free passage of water. Flotation cells form the upper part of the barge while the lower part provides space for the recovered oil. The barge is fitted with a diffusion chamber just beneath the flotation cells. A plexiglass model, shown in Figure 4, reveals the design of the oil skimmer. Oil and water flow into the skimmer sump at one end of the barge and are drawn out by a pump which transfers the liquid to the diffusion chamber. This chamber quiets the turbulence of the liquid, allowing it to pass through the many holes into the barge. The water passes out the bottom of the barge and the oil remains - thus gravity separation of oil and water is provided.

Figure 5 gives another view of the plexiglass model and permits tracing the path of oil and water from the sump to the pump, from the pump into the diffusion chamber, and thence into the storage spaces. There the oil rises to the top and the water passes out the holes in the bottom of the barge, thus keeping the barge at a constant freeboard.

The Norfolk Oil Skimmer is designed for use along a shipyard waterfront. It is not self-propelled and, therefore, the oil slick has to be drawn to the skimmer sump by means of an oil boom or washed towards the sump by salt water hoses. This requires several items of auxiliary equipment. Figure 6 shows the skimmer in operation. It will be noted that the level of water in the sump is several inches lower than the surrounding level and this waterfall effect creates a movement of surface water toward the sump. Because of this action, oil can be drawn from underneath piers and from areas between ship and berth.

The design of the oil skimmer is simple and rugged and the operating costs are extremely low. The most important feature of the Norfolk System is that the hull is used as a storage tank and that excess water leaves the barge automatically through the holes in the bottom. Therefore, the oil-water ratio is fairly unimportant with respect to the effectiveness of the system.

In rating the Norfolk Oil Skimmer on the basis of the previously established list of requirements, it will be seen that its first cost is reasonable, it has low maintenance requirements, its oil recovery rate is good, and it is relatively insensitive to water motion, and is compatible with marine life. However, the requirements for low operating expense, minimum auxiliary equipment, and mobility are not accomplished. By making the vessel self-propelled and thus avoiding booming of oil spills, these other requirements may be fulfilled satisfactorily, which makes the Norfolk System look promising for further research and development.

Other Mechanical Recovery Equipment.[4] The other devices used for oil recovery are mainly "suction hoppers" and "vacuum nozzles." The "suction hopper" is actually a steel plate box with horizontal slots near the top and a flexible suction line running from the bottom of the box to the barge pump. The "suction hopper" is lowered by a boom into the oil covered water, and the oil is recovered by a skimming process. The "vacuum process" uses approximately a 3-inch-high by 12-inch-wide nozzle and a vacuum hose up to 50-feet-long, which can be operated from a boat or the wharf. The oil-water mixture is collected in tanks and separated mechanically or by gravity.

Both methods attempt to skim the oil off the water surface. Due to the relative thinness of the oil film, it is necessary to have an accurate adjustment of the skimmer in order to minimize the subsequent oil separation process. Surface motion reduces the efficiency of this type of recovery device considerably. A rating of these methods on the basis of the previous list of desirable features indicates that only initial cost and compatibility with marine life can be scored positively.

Figure 7 shows a method of oil slick recovery which is still in use in a few places. Some absorbent material, such as straw, is spread over the oil slick to absorb the oil but unfortunately it also absorbs a considerable quantity of water. The straw is picked up by pitchforks and then burned after drying. Besides the fact that this is a "messy" operation, it is costly due to the amount of manpower and time required.

Inflatable and Semi Rigid Oil Booms.[4] The previous paragraphs indicated that, for efficient operation, oil booms are needed to support all present methods for oil recovery. Furthermore, oil booms are used to limit pollution damage and spillage losses around temporarily or permanently berthed ships, and for various emergency situations. In summary, the three general areas of application for oil booms are:

1. For oil removal operations
2. As permanent barriers
3. For emergency containment

In general, inflatable oil booms and semi rigid oil booms are in use; both types are available with and without suspended skirts.

a. Inflatable Oil Booms: Inflatable oil booms consist of a large inflatable tube, made of thin fabric-reinforced synthetic rubber, which is filled with air at approximately 40 pounds per square inch pressure. These booms are available in sections up to 50 feet in length and they can be linked by metal joints and by air hoses to allow inflation from a single point. They may also be equipped with a skirt suspended from the tube by means of a ballast chain (Figure 8).

An advantage of this type of oil boom in a permanent installation is that it can be submerged by deflating to allow a ship to pass over it, and later be easily refloated. Because the boom is collapsible, it can be carried on a truck to another place and can be inflated by the vehicle's exhaust in an emergency. A disadvantage, of course, is that the boom will sink in case of damage.

b. Semi Rigid Oil Booms: Semi rigid oil booms are used for the same purpose and in the same manner as inflatable ones. The floating part of the boom consists of cork or synthetic plastic foam with a canvas or neoprene covering. Figure 9 shows three sections of a modern pre-foamed polyethylene oil boom, equipped with a polyethylene fin as a skirt. This type of boom, sometimes referred to as an unsinkable boom, can also be removed from the water and placed in boxes for storage or transport.

The durability of oil booms, especially of the canvas cover type, is strongly affected by marine growth. Figure 10 shows a three month old canvas boom with a considerable amount of marine growth. The boom is equipped with a skirt which is wrapped around the floating part while anchored. The only way to prevent marine growth is to store the boom on land and to put it into the water just before usage. This is a costly and troublesome operation, particularly with the skirt-type booms, and valuable time is lost in case of emergency. Oil booms are undoubtedly necessary and useful equipment, but their present design, method of employment and storage are not perfect.

Oil Dissipation by Chemical Means

In contrast to mechanical oil recovery, the following methods do not recover the oil from the water; they only absorb, emulsify, or disperse the oil slick by chemical means. For this reason, the 1962 International

Conference on the Pollution of the Sea by Oil condemned all chemicals and other substances which sink, emulsify, or disperse oil slicks. At best, these methods serve to dilute oil and do not actually alleviate pollution in respect to marine life. In fact, some of the chemicals such as petroleum-based agents add to the contamination.[5]

On the other hand, there are situations where it is not possible or feasible to recover the oil and only chemical methods can solve the problem. For example, a letter written by the Norfolk Naval Shipyard[6] states: "In case of oil spills under open type pile construction, every effort will be made to wash the oil out with fire hoses and move it to such an area as will be convenient for operation of the oil skimmer. This, at times, is most difficult and as a result, it has been the practice of this shipyard to use chemical emulsifiers where the cost of labor for washing the oil out would greatly exceed the cost of using chemical emulsifiers." Unfortunately, most oil spills occur while ships are anchored or berthed and the chances that the oil will be trapped under piers and between ships are great. It is, therefore, advisable to give full consideration to chemical methods.

The use of carbonized sand, though usually unsatisfactory, is mentioned here for completeness. The method is of more physical than chemical nature and employs ordinary beach sand that has been coated with creosote oils and heat treated. The sand is blown over oil spills and tends to physically absorb and sink the oil to the bottom. It often happens that, after a period of not too many days, oil separates from the sand and rises to the water surface again.

Brief Survey of Chemical Agents.[4] Chemicals for oil slick removal are in general emulsifying and dispersing agents suitable to dissipate the surface oil into the water. There are a few exceptions such as chemicals which form a gel with the oil. This gel actually captures the oil and floats on the water surface where it can be removed by mechanical means. This method is quite costly as it involves the use of both chemicals and mechanical recovery equipment.

The chemicals in use for the dissipation of oil are normally sprayed on the slick through a nozzle under moderate or high pressure in order to stir up the water and promote interaction between the oily water and the agent. Some of the chemicals are used in concentrated form, others are mixed with sea water in proportions up to five parts of water to one part of agent. Following is a list of a few of the agents.

Agent	Manufacturer
Ara Chem	Ara Chemical Company
Emsol	DuBois Chemical Company
Oil-Mega	The Clarkson Laboratories
Oil Spill Eradicator	Camlen Chemical Company
Slix	The Penetone Company
Spill Remover	Wyandotte Chemical Company
Tricon	New Process Chemical Company
Wen-Don Formula 203	Wen-Don Chemical Company

Most companies offer a wide variety of "oil spill removers." Some of the agents currently advertised for oil dissipation are based on petroleum, some on water, and some are merely commercial detergents; the prices of these agents vary from $1.10 to $3.75 per gallon. It is difficult for shipyard personnel to make a qualified decision with regard to effectiveness, harmfulness, and economy of the available products. In some cases, the composition of oil removal agents has been changed without changing name, designation, or price.

Several specifications have been written to control the characteristics of chemical agents purchased, e.g. Military Specification MIL-S-22864 (SHIPS). Another specification, quoted below, illustrates the complexity of the problem and serves as a summary of this paragraph.

"The material required shall be an emulsifying and dispersing agent suitable for the dissipation and diffusion of spills and slicks of lubricating oils, fuel oils, vegetable oils, kerosene, gasoline and other flammable hydrocarbons.

The material required shall be a concentrate fully miscible with water in all proportions, all such mixtures remaining permanently stable. For use as a slick dispenser, the concentrate shall be first diluted in the approximate ratio of concentrate to water 1 to 3. The concentrate shall be a water-based blend of synthetic detergents and surface active agents. It shall be entirely free of all alcohol, petroleum or chlorinated solvents.

The concentrate shall be non-flammable (by the Cleveland open cup method), non-corrosive, and shall present no toxic hazard.

The application of the concentrate, diluted with water in the 1 to 3 ratio, to an oil spill shall control the evaporation rate of the flammable spills to render them non-flammable. Agitation by mechanical means shall break up and disperse the spill into discontinuous globules. In the absence of agitation, the same dispersing effect shall be gained by addition of an excess of the blended concentrate in the amount not to exceed approximately 25% of the otherwise required quantity.

The application of the concentrate-water mixture to the spill shall effect prompt dispersion of the spill. The dispersing agents shall so break up and coat the spill that it shall be incapable of future reforming of a continuous film, regardless of duration or the leaching action of the surrounding body of water."

<u>The San Diego Method of Oil Dissipation.</u>[4] Oil spills in the harbor of San Diego (Figure 1) are removed exclusively with chemical agents. The cleaning operations are performed by a contractor under a Supply Service Contract. With regard to the conditions in San Diego, outlined in the introduction of this note, the contractor is required to provide a radio dispatched boat, capable of attaining a speed of at least 12 knots. The boat has to be equipped with a high pressure pump, a spray system, and a 1,000 gallon storage tank for the liquid chemical agent. Figure 11 shows the boat during operation.

All cleaning operations are performed by a two-man crew on a 24-hour basis, seven days a week. Because tidal action in the San Diego Harbor might carry oil spills to areas where they become hazardous, the contractor's crew is required to arrive at the oil spill within one hour after notice and 30 minutes after the boat departs dockside. The chemical spray method is effective both in open water and under piers, similar to those shown in Figure 12. However, in the latter locations, an additional punt must sometimes be used. The emulsifying agent consists mainly of commercially available synthetic detergents and phosphates, but contains no solvents or inflammable components. It is claimed to be non-injurious to marine life. The contractor charges $1.15 per gallon for the chemical which is mixed 1 to 5 with sea water before use, so that one gallon of the liquid sprayed on the oil slick actually costs approximately $ .20. No separation of the oil after it emulsifies has been noted.

A demonstration of the San Diego method was impressive and it seems to be the least expensive of all methods investigated. Referring to the established list of requirements for oil removal systems, only its compatibility with marine life can be questioned and needs further proof. Of course, this method does not recover the oil which remains in some form in the water or on the bottom of the harbor.

In comparing chemical and mechanical oil slick removal, it should be noted that in general only the chemical method can be applied under all circumstances. The method is more versatile and more economical if the right agents are used. The big question is the harmfulness of emulsified oil and of the chemical agent itself to fish and marine life.

On the other hand, a constant exchange of sea and harbor water is taking place. In "A Study of Diffusion in San Diego Bay" by Marine Advisors, Inc., of La Jolla in 1963, it was reported, that the bay contains approximately 78 billion gallons of water, that a complete flushing occurs every ten days and that the half life of any dispersed material in the bay is about seven days. This means that the problem of chemical oil dissipation finally leads to the question: In what concentration really is emulsified oil deleterious? A complete answer is not available at present.

DEBRIS COLLECTION

As mentioned in the introduction, a debris problem does not exist in all harbors, and it is usually of much less importance than the trouble caused by oil pollution. In contrast to oil spills, floating debris neither presents a fire hazard nor is it dangerous to marine life; however, small boats may be endangered by driftwood. Furthermore, a considerable amount of debris tends to sink after some time. In general, the debris problem is considered as troublesome, but is given only as much attention as is absolutely necessary.

Debris may be classified, by the size of the material, into two categories:

1. Driftwood, lumber or logs
2. Garbage and cargo scraps

A considerable part of the small debris gets into the water near piers, there it collects in nooks and is difficult to remove. Figure 13 shows this kind of debris which may interfere greatly with oil recovery operations. Different pickup devices are needed to collect the two types of debris. The small items can be best collected with a large basket strainer which should be able to elevate and swing over for dumping. For large, heavy items, a powered fork or a grappling hook is required. However, advanced equipment of this kind is almost non-existent, because in many harbors the amount of debris has not yet justified the development of new equipment. Therefore, manual labor is still relied upon, especially for removal of the larger debris items. Figure 14 shows a laborer collecting driftwood and lumber into a small barge towed by a converted LCM. The only mechanical device used by the workman is the hand winch for long or bulky items.[4]

The only modern equipment for debris collection encountered in this study was designed in England (Figure 15).[4] The vessel is 18-feet-long, of steel construction, and is propelled by a 30 horsepower inboard diesel engine which gives it a maximum speed of approximately eight knots. Horizontal fins are provided at the hull to reduce pitching during debris collection. The scoop-strainer at the bow is of steel tube design and is hydraulically actuated and controlled. The scoop-strainer can lift up to 2,150 pounds, can submerge to a depth of four feet, and will elevate to 11 feet. The vessel appears to be suited to collection of small as well as large pieces of debris. Since the only two vessels of this kind in existence are in Liverpool, the information obtained so far is limited and further investigation will be required for a final evaluation.

Debris collection is normally a tedious and manpower-consuming operation, especially because of lack of modern equipment. The problem rarely becomes serious but even routine operations are quite a burden for some harbors. Although debris collection is not one of the major maintenance expenses at most harbors, it can easily amount to $10,000 per year. The short review of the current methods and equipment indicates that debris collection in general is outdated and costly. An extensive development and test program is necessary to improve the present situation.

RECOMMENDATIONS AND FUTURE PLANS

1. The study indicated that chemical oil dissipation can be a harmless, effective, and economical process but unfortunately the use of inappropriate agents often produces opposite results. Therefore, an investigation of

chemical agents with regard to harmfulness, effectiveness, practical application and economic aspects is recommended. The objective should be to define a number of products commercially available which qualify for use by the Navy and to develop easily applicable check out procedures.

2. Present methods of debris collection call definitely for improvements in this area. It is recommended that an investigation be made to determine the most suitable type of collection device and to develop drawings and specifications for such a piece of equipment.

3. Future plans include the improvement of methods and auxiliary equipment for mechanical oil recovery operations and for emergency situations. Eventually, the physical recovery of accidentally spilled oil is the best and most logical answer to water pollution control. More specifically, test and evaluation of the Earle System and a program for improvement of oil skimmers are planned for the near future. - The importance of oil booms and on the other hand, the known deficiencies of this equipment recommend further investigation to improve their design and methods of operation.

As a result of this study, three improvement areas with a high probability of pay off have been established:

Investigation of agents for chemical oil dissipation
Development of methods and equipment for debris collection
Improvement, test, and evaluation of equipment for mechanical oil recovery.

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4. Information and brochures received from various companies and Centers concerned with harbor cleaning operation.

5. Pollution of the sea by oil. New York, United Nations, 1956.

6. Letter of 4 December 1964 from Commander Norfolk Naval Shipyard to Acting Chief, Industrial Division, Panama Canal Company.

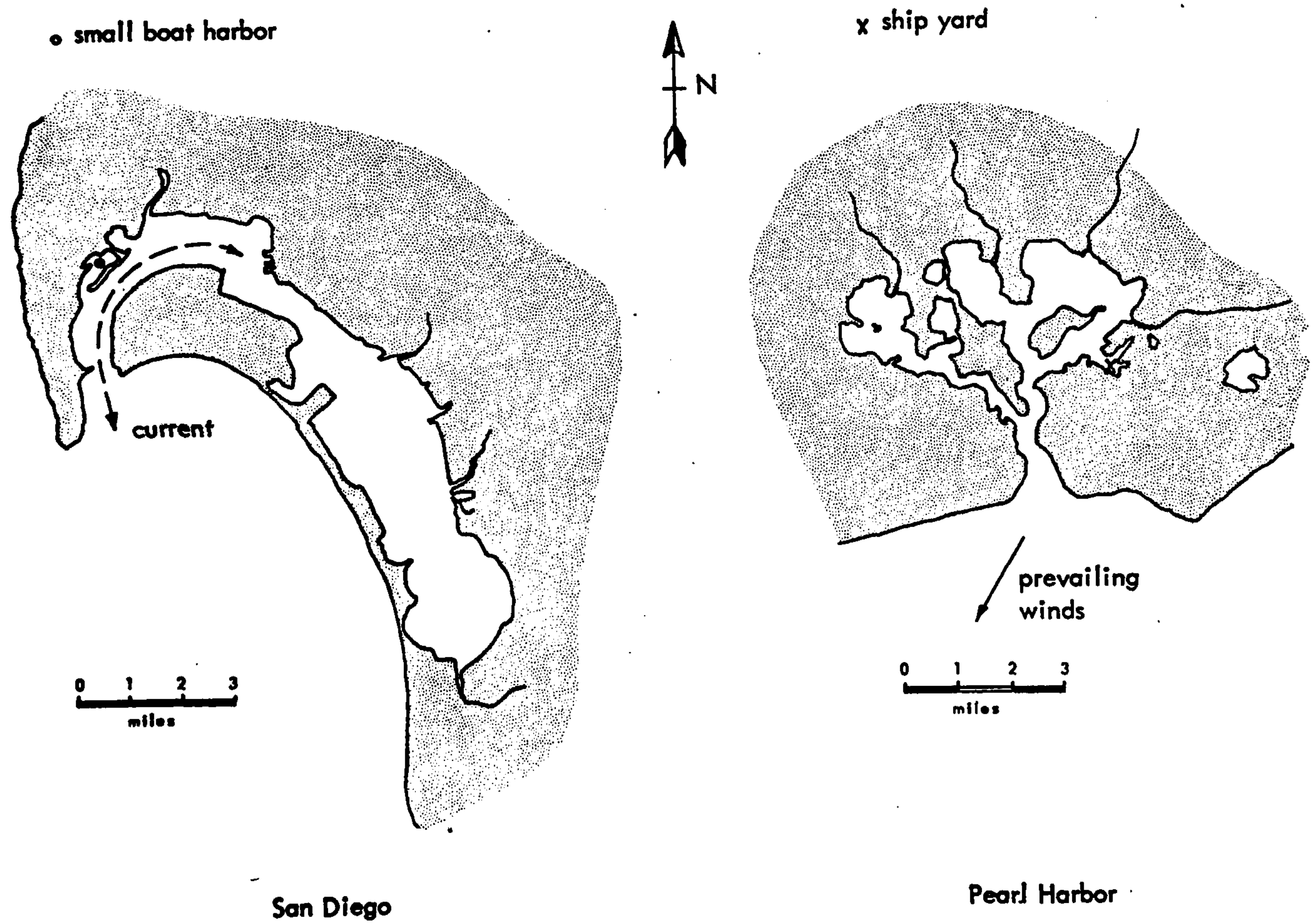

Figure 1. Comparison of the topography of San Diego and Pearl Harbor.

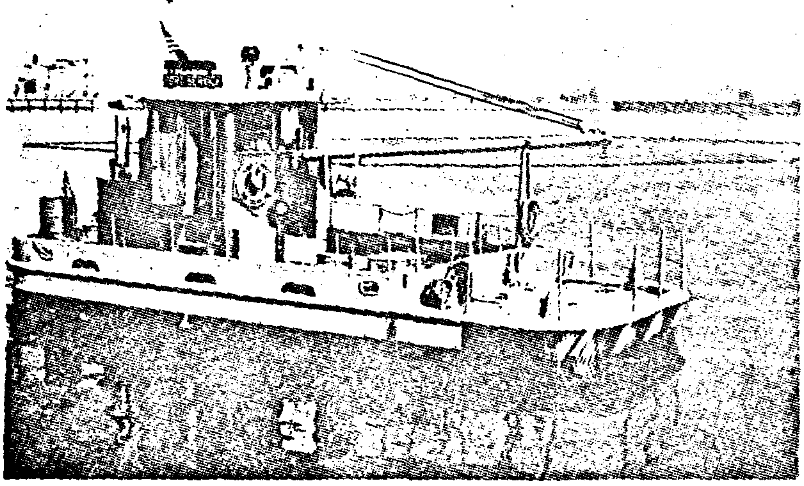

Figure 2. The Baltimore oil recovery barge.
(Courtesy of Surface Separator, Systems Inc., Baltimore, Md.)

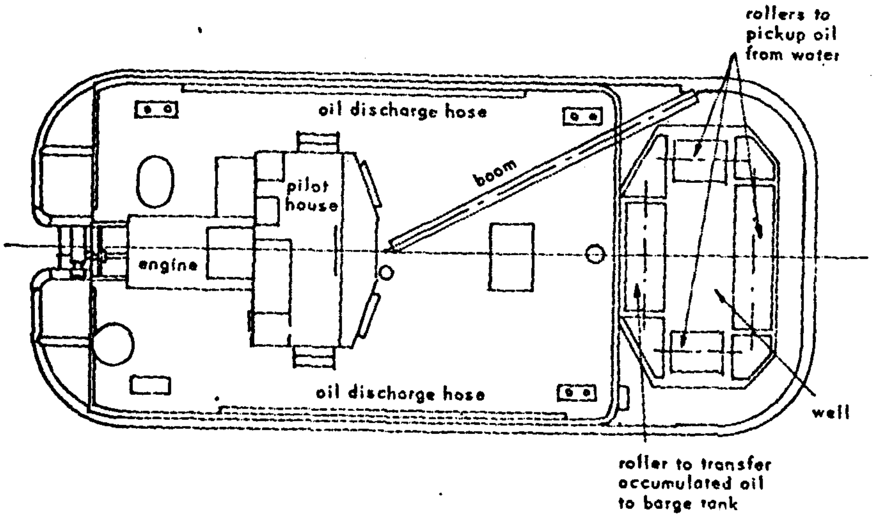

Figure 3. Plan of the Baltimore barge.
(Courtesy of Surface Separator, Systems, Inc., Baltimore, Md.)

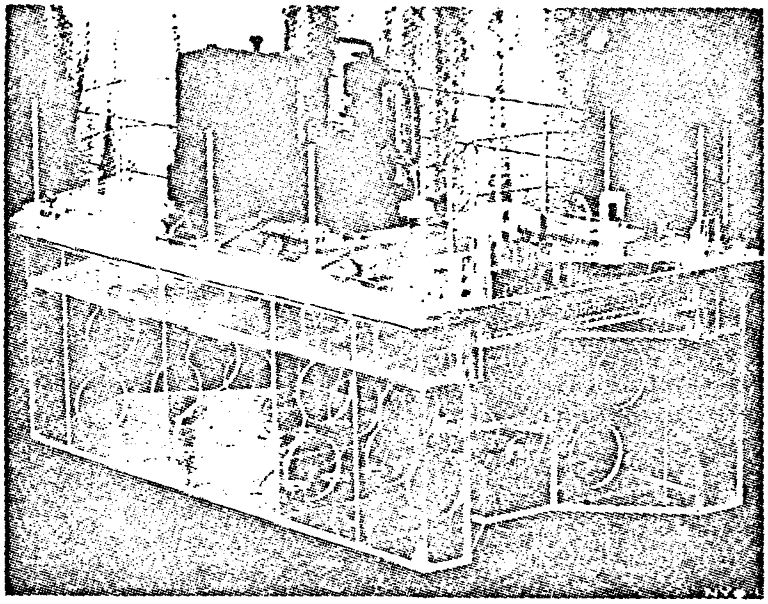

Figure 4. Plexiglass model of the Norfolk Oil Skimmer, three-quarter view.

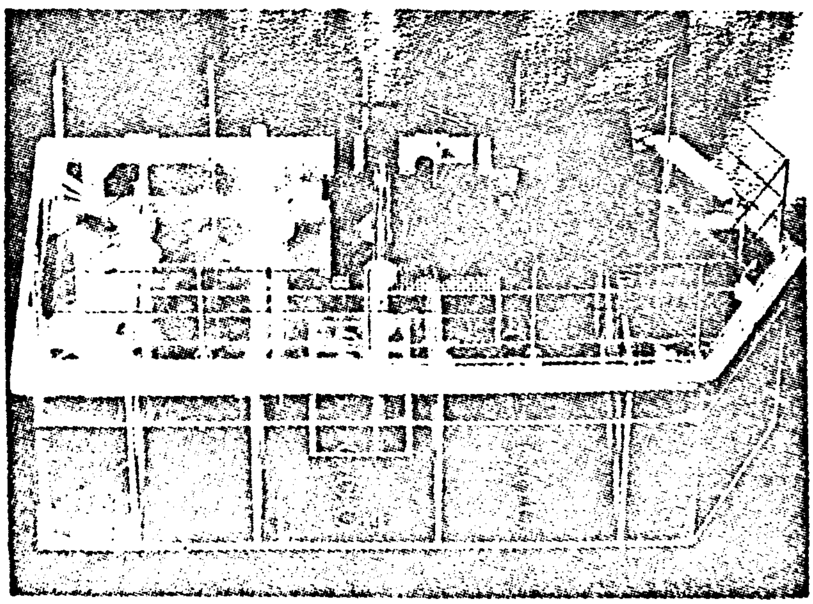

Figure 5. Plexiglass model of the Norfolk Oil Skimmer, top and side view.

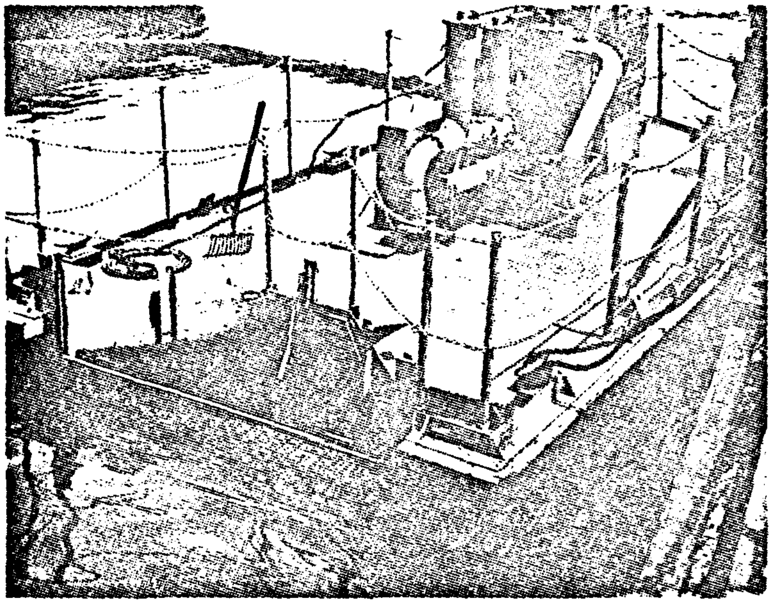

Figure 6. Norfolk Oil Skimmer in operation.

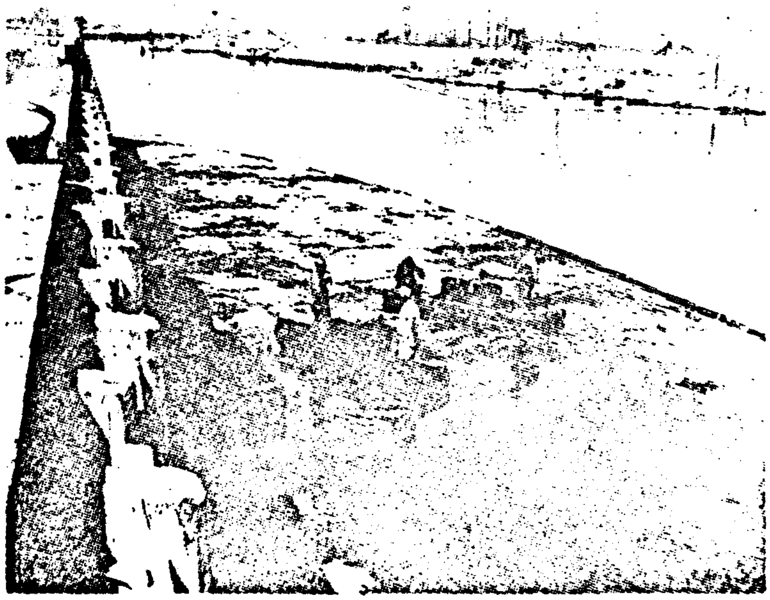

Figure 7. Oil slick recovery by means of absorbent material.

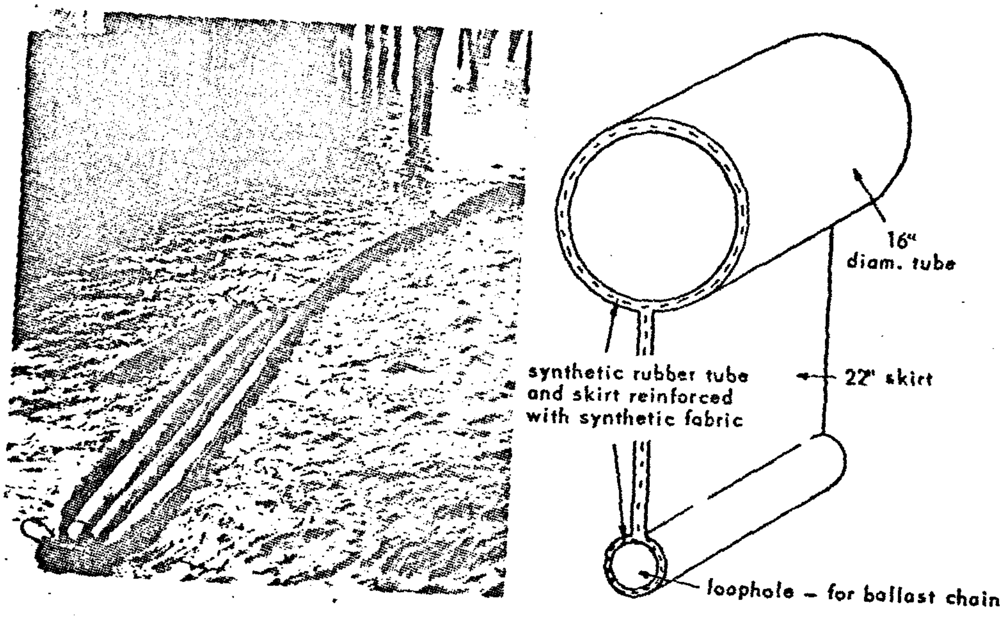

Figure 8. Inflatable oil boom with skirt; left: 25- and 50-foot-long sections with connecting hoses, right: section through boom. (Courtesy of Surface Separator, Systems, Inc., Baltimore, Md.)

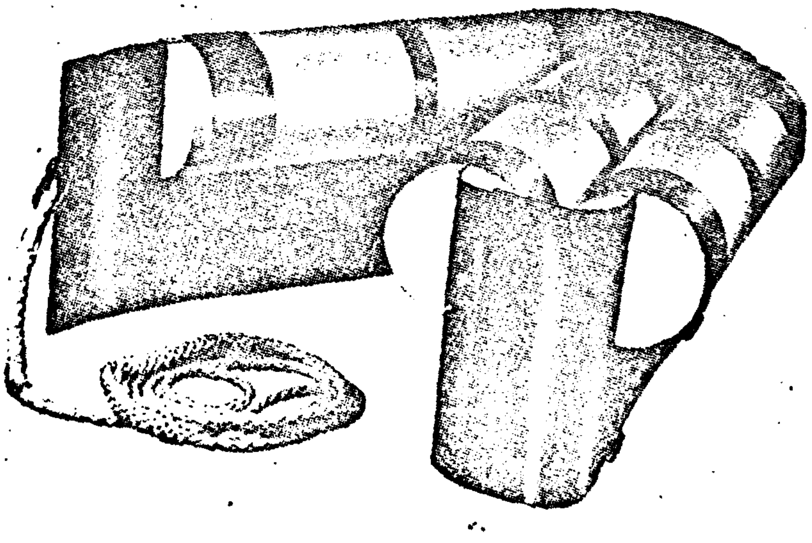

Figure 9. Three sections of semi-rigid, pre-foamed polyethylene oil boom with polyethylene fin as skirt. (Courtesy of Neirod Industries, Inc., Saugatuck, Conn.)

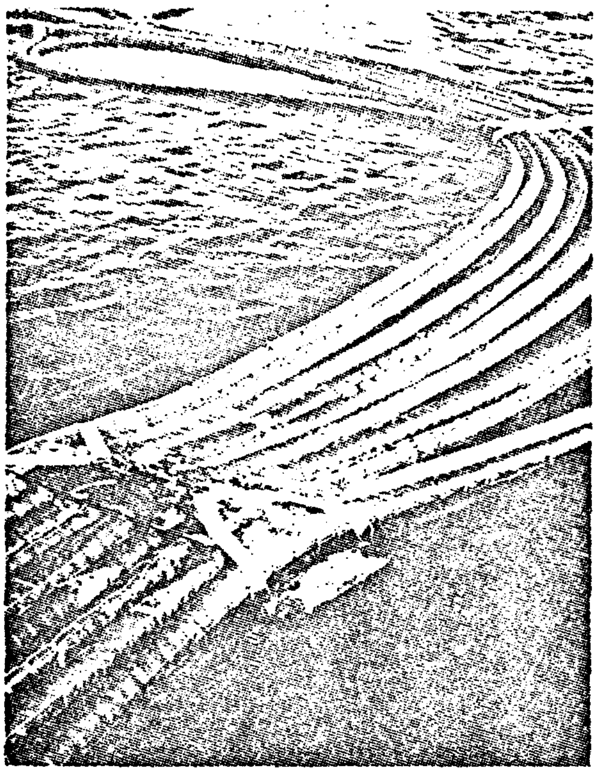

Figure 10. Cork-filled oil boom with canvas cover attacked by marine growth.

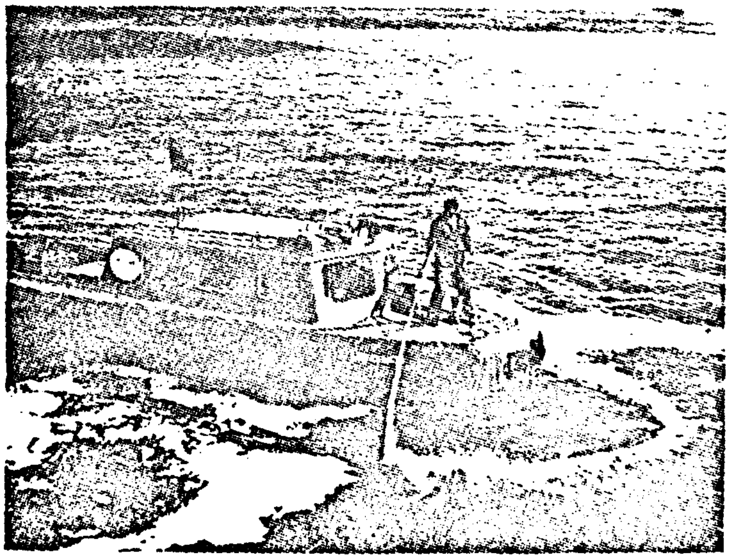

Figure 11. Chemical oil dissipation in San Diego Harbor.

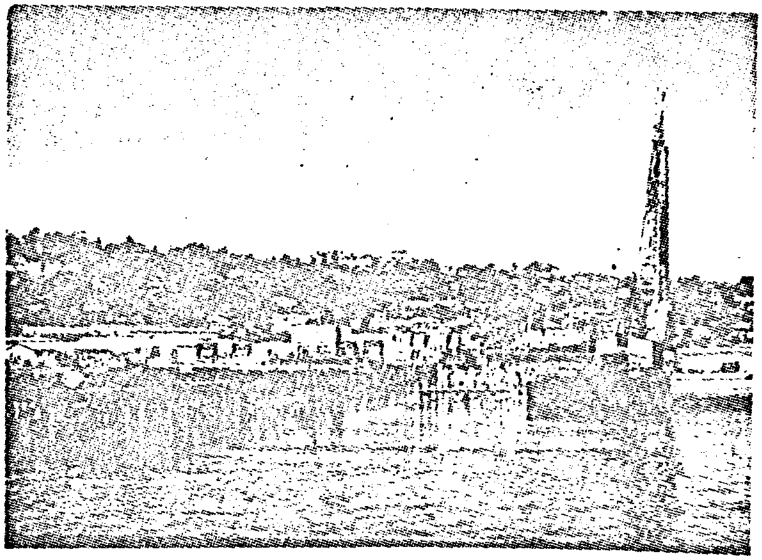

Figure 12. Pier construction in San Diego Harbor.

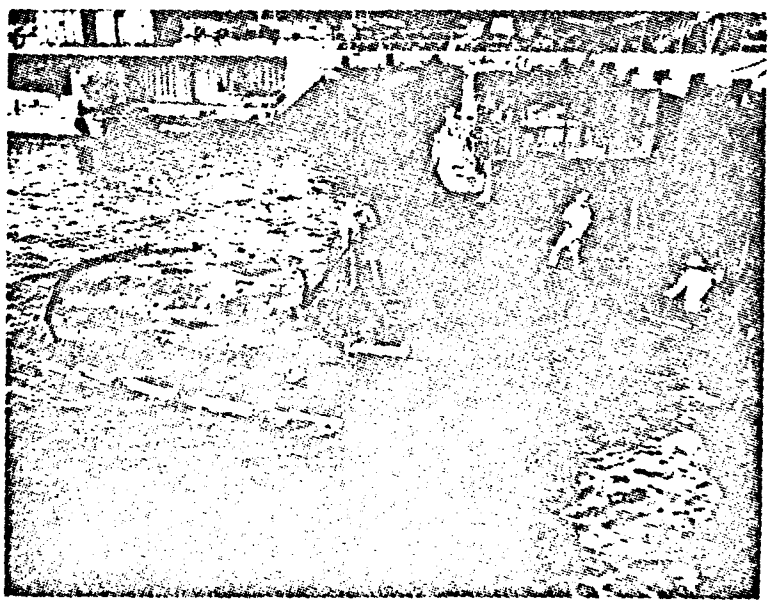

Figure 13. Oil slick containing great amount of garbage is encircled by oil boom and drawn towards oil skimmer float.

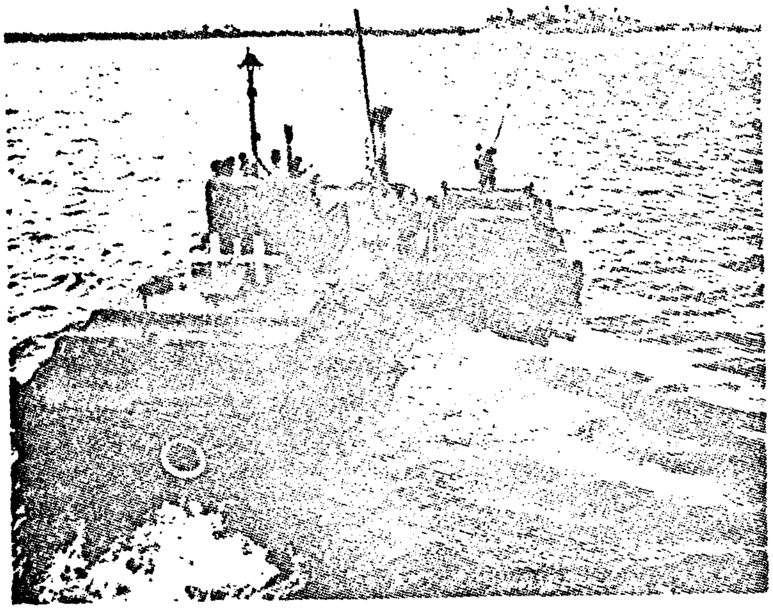

Figure 14. Manual collection of debris.

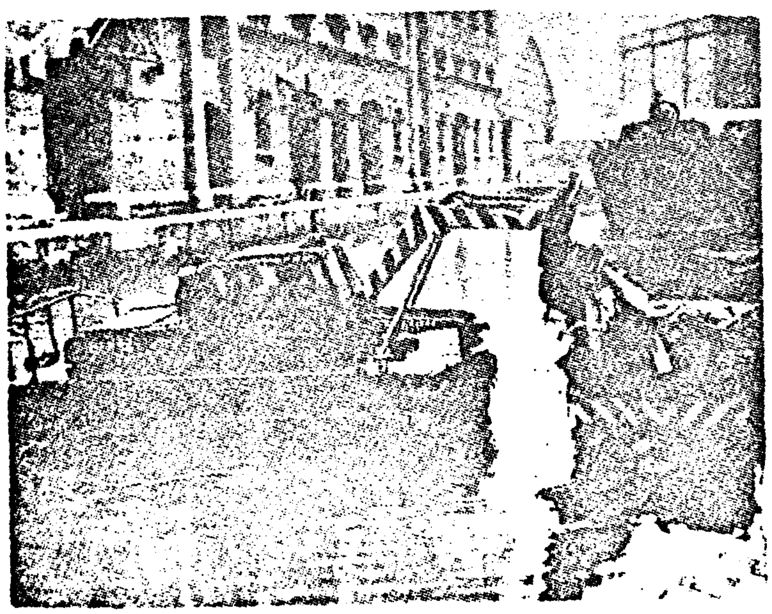

Figure 15. Modern equipment for debris collection.
(Courtesy of Bootle Barge Company, Liverpool, England.)